B45C-1633: Quantifying watershed scale Longleaf Pine (*Pinus palustris*) evapotranspiration effects on streamflow using the long-term water balance

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Background

- Longleaf pine savannahs once covered 90 million acres but have dwindled due to favor for faster growing plantation species
- Longleaf pine (*Pinus palustris*) savannahs transpire less water than Loblolly pine (*Pinus taeda*) or Slash pine (Pinus elliottii) plantations and some hardwood species due to lower leaf area, native groundcover, and drought tolerant Longleaf pine physiology
- Model simulations and case studies indicate that Longleaf restoration increases streamflow but there are few published data

Longleaf pine Savannah at the Jones Center at Ichauway

Loblolly pine plantation in Georgia
David Stephens, Bugwood.org

Research Questions

- How does forest cover type affect mean annual streamflow?
- Do watersheds with Longleaf pine have higher low-streamflow than those without?

Study Watersheds

Figure 1: Map of gaged USGS watersheds within the historic range of Longleaf pine ecosystems in the southeast U.S. coastal plain with ≥24% forest and ≤ 10% developed area. Nine have 15-72% Longleaf and twelve have 0-3% Longleaf.

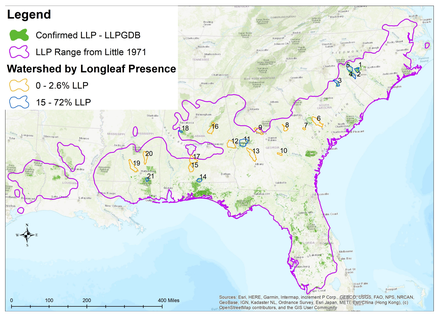


Figure 3: Basal area for dominant species from Forest Inventory and Analysis plots in the study watersheds.

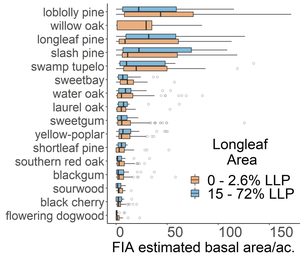


Figure 2: Land cover distributions within the study watersheds. Longleaf pine area is from the Southeast Longleaf Pine Database and other types are from NLCD

Forest is the dominant land cover type

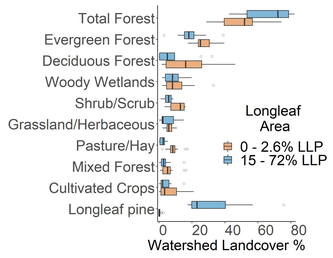


Table 1: Selected watersheds with Ids, U.S. Geological Survey site numbers, drainage areas (DA) and Longleaf pine coverage.

Id	USGS #	Station Name	DA (km^2.)	LLP %
1	02102908	Flat Creek Near Inverness, Nc	19.76	72.38
2	02104220	Rockfish Creek At Raeford, Nc	241.13	59.43
3	02130900	Black Creek Near Mcbee, Sc	279.72	22.99
4	02132320	Big Shoe Heel Creek Nr Laurinburg, Nc	215.75	14.86
5	02133500	Drowning Creek Near Hoffman, Nc	473.97	18.77
6	02175500	Salkehatchie River Near Miley, Sc	883.19	1.34
7	02198100	Beaverdam Creek Near Sardis, Ga	79.77	0.00
8	02201000	Williamson Swamp Creek At Davisboro, Ga	282.31	0.00
9	02213500	Tobesofkee Creek Near Macon, Ga	471.38	0.00
10	02216180	Turnpike Creek Near Merae, Ga	127.43	0.00
11	02341800	Upatoi Creek Near Columbus, Ga	885.78	19.77
12	02342500	Uchee Creek Near Fort Mitchell, Al.	833.98	1.60
13	02351890	Muckalee Creek At Ga 195, Near Leesburg, Ga	937.58	0.19
14	02360800	Blackwater River Near Bradley Al	227.14	34.15
15	02374500	Murder Creek Near Evergreen Al	455.84	0.00
16	02408540	Hatchet Creek Below Rockford Al	681.17	2.63
17	02427250	Pine Barren Creek Near Snow Hill, Al.	675.99	0.00
18	02465493	Elliotts Creek At Moundville Al	83.66	22.54
19	02472500	Bouie Creek Nr Hattiesburg, Ms	787.36	0.07
20	02473500	Tallahala Creek At Laurel, Ms	616.42	0.00
21	02479155	Cypress Creek Nr Janice, Ms	136.23	40.20

Data

Streamflow: USGS 1989—2021 (32 years)

Climate data: GridMET Dataset

Landcover: National Landcover Dataset (NLCD) combined with the Southeast Longleaf Pine Database from the Florida Natural Areas Inventory

Species composition: Forest Inventory and Analysis Database

Leaf Area Index: 2014—2020 Copernicus Satellite 300 m pixel values summarized to growing season watershed mean LAI

Methods

Water Balance ET: We estimated annual evapotranspiration (ET) using the long term water balance method for the 1989—2021 water years.

ET = Precipitation - Streamflow - ($\Delta S/\Delta t$)

$\Delta S/\Delta t$ = changes in storage average out over long term

Relationships among WB-ET, abiotic and biotic variables were assessed with linear models and AIC.

ET was quantified relative to Budyko predicted ET

Results

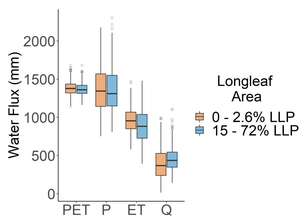


Figure 4: Mean annual Penman Monteith Potential Evapotranspiration (PET), precipitation (P), water balance estimated Evapotranspiration (ET), and streamflow (Q) for the study watersheds.

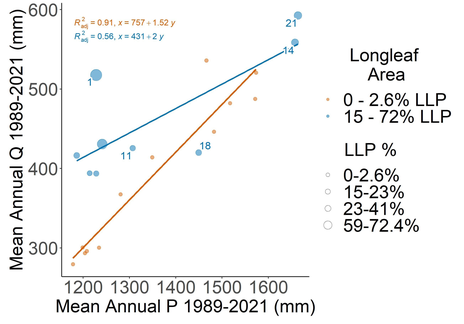


Figure 5: Mean annual streamflow (Q) by precipitation (P).

Many Longleaf watersheds have lower P but high Q relative to watersheds without Longleaf.

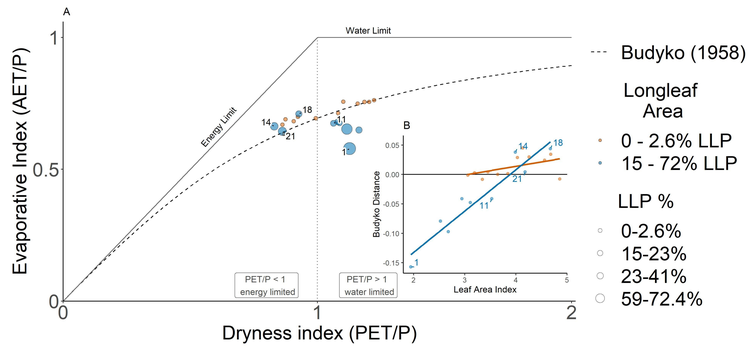


Figure 6: Mean annual watershed evapotranspiration in the Budyko framework.

Watersheds with Longleaf pine and low LAI have lower mean annual evapotranspiration than predicted by the Budyko equation

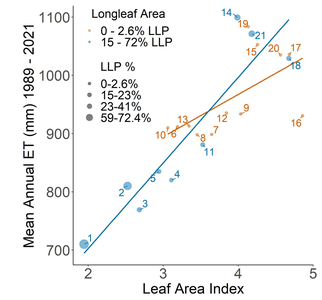
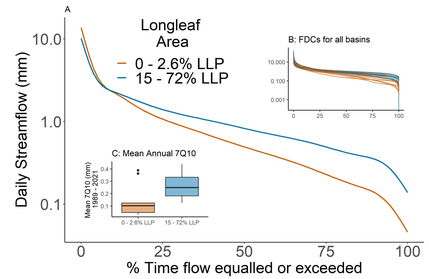


Figure 7: Leaf Area Index (LAI) by mean annual evapotranspiration (ET).

Higher LAI and differing species composition in Forest Inventory and Analysis plots explain why three watersheds with Longleaf pine have higher ET and lower annual streamflow.

Figure 8: A.) Mean flow duration curves by watershed group, B.) Flow duration curves for all watersheds, C.) Boxplots of 7Q10 low flow statistics.

Watersheds with Longleaf pine forests have higher mean annual low flows.



Conclusions

- **Watersheds with Longleaf pine and LAI <3.5 have higher mean annual streamflow, lower mean annual ET and higher low flows than watersheds without Longleaf or those with Longleaf and higher LAI.**
- **Three watersheds with Longleaf pine, higher mean LAI, and differing species composition had streamflow and ET rates similar to watersheds without Longleaf.**
- **This is the first long term multi-watershed water balance evidence of higher water yield from Longleaf pine forests.**

Ongoing and future work

- Watershed modeling of different Longleaf pine management strategies (plantation growth, pine straw production, wildlife, fire, etc.)
- Coupling hydrologic scenarios with economic scenarios to quantify influences for private landowners

Young planted Longleaf pines may transpire more than mature ones due to higher densities

Prescribed fire plays an important role in managing the understory. The Jones Center maintains an average fire return interval of two years.

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References:

J. Qi, S.T. Brantley, S.W. Golladay, Simulated irrigation reduction improves low flow in streams—A case study in the Lower Flint River Basin, Journal of Hydrology: Regional Studies, Volume 28, 2020, 100665, ISSN 2214-5818

Golladay, S. W., Clayton, B. A., Brantley, S. T., Smith, C. R., Qi, J., and Hicks, D. W.. 2021. Forest restoration increases isolated wetland hydroperiod: a long-term case study. *Ecosphere*. 12(5):e03495. 10.1002/ecs2.3495